(Feature Article) Master craftsmen of the Kalahari

The Ju|'hoansi San people of the Kalahari: master crafters of composite arrows

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The San people of Southern Africa are considered by many to be the most ancient race of people in the world. They are nomadic, egalitarian, hunter-gatherers, many of whom have maintained much of their lifestyle, despite widespread marginalisation of their communities in Southern Africa. Divided into three main nations (the !Kung, the Tuu and the Tshu-Khwe) and further into a plethora of groups/sub-groups, here, we focus on the Ju|'hoansi San people, Figure 1, a Southern !Kung group located in the Kalahari desert (North-West Namibia/North-East Botswana) and comprising *circa* 1400 people living in 36 N!oresi (villages). The Ju|'hoansi are one of the few San groups who are still able to practice their hunter-gatherer lifestyle, though the breadth and freedom of their practices have been considerably limited by law.

Figure 1. A Ju|'hoansi family living in the Kalahari desert of North-Western Namibia.

Tools of the Ju|'hoansi people

The tools of the Ju|'hoansi can be divided into three broad categories; those used for gathering, general everyday tools, and hunting tools. Gathering cloaks (Kaross) (Figure 2) are typically made from animal skins originating from large antelopes such as eland or kudu. Sharpened wooden tools, or combined wood-iron tools, are usually used for digging for foods and other useful materials. General tools may include fire-hardened woods to create a pestle and mortar, quivers made of fire-hardened hollowed tree roots (Figure 2), and male-female sticks for starting fires. The Ju|'hoansi hunting tools (bow and arrow, and spear) are perhaps the most technically significant, exhibiting careful and well-planned engineering designs. This article will focus on the

assembly-procedures, materials selection, and geometrical designs of the Ju|'hoansi arrows (Figure 2) and is based on research insights developed by The Materials Modelling and Design team at The University of Edinburgh.

Figure 2. Hollowed out tree root to make a quiver (top left), an example of an arrow (top right) and a gathering cloak, or Kaross (bottom).

Ju|'hoansi arrows – materials and manufacture

The Ju|'hoansi have invested considerable time and effort into developing the composites and adhesives that leads to the manufacture of each arrow. So much so, that each stage of manufacturing is critical for a successful final product, which typically takes three days from start to finish. The process is naturally slow since there are curing times for adhesives, speciality methods of preparing arrowhead parts, and each procedure is completed by hand. Figure 3 provides examples of arrowheads made of root (*Rhus tenuinervis*), shinbone (of giraffe) and ductile iron (a material introduced during the German occupation of 1884), each of which is inserted into a hollow reed (*Phragmites sp.*). With the exception of these arrowheads, the majority of other materials used to construct the arrows are common to them all. This includes the reed (*Phragmites sp.*) forming both the reed shaft (all arrows) and the reed link shaft, a thinner reed connecting the bone-to-bone and metal-to-bone in the bone and metal-tip arrows. Also included are two separate types of glue, one of which is viscous amber sap from the trunk of the tree *Terminalia sericea*, while the other is a composite comprising milky latex exude from the roots of the *Ozoroa schinzii* bush mixed with the fine black ash of freshly burnt *Aristida adscensionis* grass. Giraffe and kudu tendons (from the Achilles) are also used in the making of these arrows, and each arrowhead is finally tipped with a deadly poison usually extracted from the grub of Chrysomelid (leaf) beetles (*Diamphidia sp*. and *Polyclada sp*.). These grubs are typically dug out from the base of *Commiphora sp*. or *Sclerocarya birrea* trees, at about a foot below the surface of the ground.

Figure 3. A *Rhus tenuinervis* root arrowhead (top) giraffe shinbone arrowheads (middle three) ductile iron arrowheads (bottom two)

It is generally understood, that the chronological order of materials used to construct arrowheads began with the root, was followed by bone, and ended with the ductile iron. Nevertheless, all three arrowheads are still in use by the Ju|'hoansi, the root arrowheads being preferred for the close range hunting of small sized prey, while the bone and metal arrowheads are used to hunt larger prey at longer ranges.

Ju|'hoansi arrows – design

The Ju|'hoansi arrows are for the most part, composites made up of natural materials. Reeds (*Phragmites sp.*) form the main shaft in all arrow types. The cellulose fibres of these reeds grow unidirectionally along the length of the reed. This means the reeds are of high stiffness and strength along their lengths but are weak in their transverse directions. Since the arrow heads are wider than the reeds, and are inserted and firmly fixed into them, the reeds will fail between the fibres through forced transverse contact with the arrowhead. To circumvent this problem, the Ju|'hoansi reinforce the portion of the reed that will bear the transverse forces exerted by inserting the arrowhead. They reinforce the reed by first wetting the carbonised black *Ozoroa schinzii* glue and then applying it to the surface of the region for reinforcing. Following this, they tear thin strips (approximately 0.5mm thick × 1-2mm wide) of water saturated giraffe tendon, which they wind around the reed over the surface of the *Ozoroa schinzii* glue.

They conduct the same procedure for the reed link shaft observed in the bone-tip and metal-tip arrowheads (*cf*. Figure 3). Once dried, the glue fixes the tendon tightly to the surface of the reed shaft/link shaft, and the tail end of the arrowhead is covered in *Terminalia sericea* glue after which it is inserted firmly into the reed. In the cases of the bone-tip and metal-tip arrowheads, the same procedure takes place with the appropriate ends of the arrowhead parts being glued and inserted into the reed link shaft as well.

Figure 4 (a) Cutting of the *Ozoroa schinzii* root, which after heating expels a milky latex that is subsequently mixed together with (b) ashes of *Aristida adscensionis* grasses (c) the finished latex/ash adhesive is shown attached to the stick at the top, while the adhesive attached to the lower stick is the amber sap of the *Terminalia sericea* tree (d) an the root of a *Rhus tenuinervis* plant is cut to a balanced arrowhead while still wet.

Figure 5. Application of the latex/ash adhesive by wetting and rubbing to the surface of *Phragmites sp.* reeds before giraffe tendon is wrapped transversely around the reed to create an affixed composite reinforcement (left) giraffe shinbone is cut to a sharp point before it is inserted into the *Phragmites sp.* reed link shaft – amber sap adhesive from the *Terminalia sericea* tree is used to glue the arrowhead to the inside of the reed link shaft.

To balance the weight of the arrowheads from tip to shaft, the Ju|'hoansi counterweight their arrowheads. This decreases tilting problems when the arrows are fired. In the case of root-tip arrows, loss of material towards the tip of the arrowhead is balanced by preserving a thick section of the root at the shaft-end of the arrowhead. The procedure is slightly more complicated for the bone-tip and metal-tip arrowheads, as the counterweights are essentially, large pieces of giraffe shinbone, with slightly more bulbous geometries than the arrowhead tips. These counterweights are chaffered down at the ends to fit into both the reed shaft and the reed link shaft. The tips of these types of arrows are more finely constructed, both being long and thin in comparison to the bulbous counterweights. Wet giraffe shinbone based tips are manufactured by cutting and grinding, while ductile iron is heated over coals and hammered, cut and ground into shape. The Ju|'hoansi typically use metal iron fencing that they find in their localities. Interestingly, the geometries of the arrowhead tips are widely varied and this is understood to relate to the density of the material used to make the tip. The root tips, which are the largest, are also of the lowest density (0.9g/cc), while the smaller bone tips are higher density (2.0g/cc) they are not as dense as the ductile iron tips (7.6g/cc), which are geometrically, the smallest of the three arrowhead types. This indicates that the Ju|'hoansi arrows are geometrically designed *as well as* manufactured, as a response to their material and physical properties.

We may further note that there is a design logic in how the reed link shaft is used. It would not for example, be any more time consuming to create a single part arrowhead in the bone-tip and metal-tip arrows, in similitude to the root-tip arrow. Yet, the

Ju|'hoansi preferentially design these in three separate parts, the central part being a composite joint made of giraffe tendon reinforced reed. Following discussions conducted with the elders of a Ju|'hoansi family, we understood that these were in fact purposely made to break. Whereas a root arrow is a short-range projectile that can easily be recovered, the longer range of use of the bone-tip and metal-tip arrows means that these arrows can be easily lost, either in a distant hunting ground, or while attached to a fleeing animal. Arrows are vital tools for hunting and their reuse and recyclability can save precious time and natural resources. As such, the Ju|'hoansi design the arrow-tips of the bone-tip and metal-tip arrows in such a way that they will break off after impacting and penetrating an animal. Animals such as giraffe or eland are large and the poison takes time to spread. While the Ju|'hoansi track their kill (which may take up to 3 days for large, strong mammals), they can retrieve the majority of the rest of their arrow, which will typically break off at the reed link shaft where the hunt took place. This allows the Ju|'hoansi the opportunity to reuse much of the arrow, only having to replace the reed link shaft and the tip, should the tip not be found with the dead animal.

Final remarks

Today, the San people's hunter-gatherer lifestyle is critically under threat. They have been marginalised to the extent that many San groups now accept handouts of game that has been hunted by foreigners. Anthropologists predict the San way of life has less than 25 years before it ceases to exist altogether. The Ju|'hoansi San are living models of humanity's history yet, very little is known about the design parameters they have manipulated to satisfy the specific functional requirements of their hunting tools. Their arrows are exemplars of function-specific engineering and design, are manufactured using simplistic tools, and are made primarily of natural materials sourced from the local environment. They have been designed to be balanced in flight, lightweight and aerodynamic, to be recoverable and reusable, and to be damage tolerant. The Ju|'hoansi are the composite arrow master crafters of the Kalahari, and have developed their technologies over 200,000 years of trial and error.